TAXONOMY OF MEDICINAL PLANTS FROM TROPICAL RAINFORESTS AND THERAPEUTIC CATEGORIES OF THEIR DRUG DERIVATIVES

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ABSTRACT

Taxonomic position of 47 medicinal plants from tropical rainforests yielding clinically useful drug derivatives is described. Therapeutic categories of the drug derivatives from these plants are mentioned. These plants belong to 46 genera in 31 families of angiosperms and yield more than 100 derivatives. Families Apocynaceae, Fabaceae, Rubiaceae and Solanaceae included four species each, followed by Acanthaceae, Asteraceae, Brassicaceae and Lauraceae having two species each of medicinal plants. The remaining 23 families, including a monocotyledonous family Arecaceae, had one species each of medicinal plants. Exploitation of rainforest plants may provide further drug derivatives that will alleviate or correct every known human ailment.

KEY WORDS: Rainforests, medicinal plants, taxonomy, drug derivatives, therapeutic categories.

Tropical rainforests are green, lush forests that support a tremendous amount of species. These forests are typically located within a narrow band four degrees either side of the equator. Although it is the Amazon rainforests that spring most readily to mind, it is

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important to remember that they are also found in parts of central and south America, Africa and Madagascar, south and southeast Asia, New Guinea and Australia, the Philippines and Malaysia, and Hawaii (Allo, 1996). All these rainforests are located near the equator, but each of these forests is separated by thousands of miles and is unique (Terborgh, 1992). Tropical rainforests are mainly the product of climatic interactions, particularly temperature and rainfall. High temperatures in the rainforests cause high evaporation that result in frequent rain. In general, tropical rainforests occur where a mean monthly temperature between 20 and 28° C is combined with an annual rainfall between 1.5 and 10 meters, evenly distributed throughout the year (Terborgh, 1992).

Rainforests play an important role in the climate of our planet by having an effect on the wind, rainfall, humidity, and temperature. Within the rainforest, water, oxygen, and carbon are recycled. This natural recycling helps to reduce flooding, soil erosion, and air pollution. The rainforests support over one half of the plant and animal life on earth (Terborgh, 1992). While tropical forests only constitute about 7% of the earth's surface, they account for 50-80% of the world's plant species. These forests, with their mighty trees and extraordinary flora and fauna, constitute the planet's richest habitats, and one of our most precious natural resources (Allo, 1996; Terborgh, 1992).

Rainforests contain an amazing abundance of plant life. About one hectare of Amazon rainforest is believed to house approximately 900 tons of botanicals. Approximately one fourth of the pharmaceuticals (medicines) we use come from plants of the tropical rainforests (Duke, 1997; Foster & Duke, 1990; Joyce, 1994; Moerman, 1996). It is exciting that scientists and researchers have begun to uncover the medicinal properties of rainforest herbs and flora (Farnsworth, 1988; Iwa et al., 1999; Joyce 1994). Nature has provided us with a treasure of herbal remedies-secrets that offer new approaches to health and healing. It is interesting to note that 70% of the plants from which we derive medicines that are effective in the treatment of cancer can only be found in the rainforests (Taylor 2004).

Classification of medicinal plants is organized in different ways depending on the criteria used. In general, medicinal plants are arranged according to their active principles in their storage organs, particularly roots, leaves, flowers, seeds and other plant parts (Athar & Ahmad, 2004; Athar & Nasir, 2004; Athar & Siddiqi, 2004; Duke 1997; Moerman, 1986, 1991, 1996). These principles are valuable to humans for treatment of different diseases (Ebadi, 2002; Palaniswamy, 2003; Ross 2003). This paper describes the taxonomy of medicinal plants from tropical rainforests and summarizes the therapeutic category of the useful drug derivatives obtained from them.

MATERIALS AND METHODS

A literature search was conducted to determine medicinal plants from tropical rainforests (Arvigo & Balick, 1993; Duke, 1997; Ebadi, 2002; Farnsworth, 1988; Foster & Duke, 1990; Iwa et al., 1999; Joyce, 1994; Moerman, 1986, 1996, 1996; Palaniswamy, 2003; Schultes & Raffauf, 1990; Taylor, 1998, 2004; Werbach & Murray, 1994), and their taxonomic position was determined. Only those plants were reported which were frequently mentioned in the literature. The genera were arranged alphabetically within families. The scientific and common names are provided that are generally associated with these plants. It is pointed out that common names are very imprecise and often assigned to completely different plants, so the scientific name should be used when looking for additional information concerning a plant. The paper also summarizes the therapeutic categories of the useful drug derivatives obtained from these plants. The nomenclature and classification followed Bailey & Bailey (1976), and author citations followed Brummitt & Powell (1992).

RESULTS AND DISCUSSION

The taxonomic position of 47 medicinal plants from tropical rainforests yielding clinically useful drug derivatives is presented in Table 1. It lists the more important medicinal species, including those from which many of our prescription drugs are derived. These species belong to 46 genera in 31 families of angiosperms and yield more than

Table 1. Taxonomy of plants from tropical rainforests yielding clinically useful drugs and their therapeutic categories.

Species	Common Name	Compound Derived	Therapeutic Category
MONOCOTYLEDONS			
Arecaceae (Palmae)			
Areca catechu L.	Betek-nut palm	Arecoline	Anthelmintic
DICOTYLEDONS			
Acanthaceae			
Andrographis paniculata (Burm. f.) Wall. ex Nees	Karyat	Andrographolide	Anti-bacterial
		Neoandrographolide	Anti-dysentery
Justicia adhatoda L.	Malabar nut	Vasicine (Peganine)	Oxytocic
Amaranthaceae			
Hebanthe eriantha (Poir.) Pedersen	Suma	Numerous including allantoin, sitosterol, daucosterol, pfaffosides, saponins, stigmasterol	Aphrodisiac, anti-cancer, immune enhancer
Anacardiaceae			
Schinus molle L.	Brazil peppertree	Calamenene, camphene, carvacrol, myrcene, pinene, quercitin, quercitrin,	Astringent, diuretic, urinogenital, venereal disease, viricide
Apiaceae (Umbelliferae)			
Centella asiatica (L.) Urb.	Indian pennywort	Asiaticoside	Vulnerary

Apocynaceae			
Catharanthus roseus (L.) G. Don	Madagascan periwinkle	Vinblastine	Anti-tumor agent
		Vincristine	Anti-cancer
Rauvolfia serpentina (L.) Benth. ex Kurz	Indian snakeroot	Ajmalicine	Circulatory stimulant
		Rescinnami	Anti-hypertensive
		Reserpine	Anti-hypertensive, tranquilizer
Rauvolfia tetraphylla L.	Snake root	Deserpidine	Anti-hypertensive, tranquilizer
Strophanthus gratus (Wall. & Hook.) Baill.	Twisted flower	Ouabain	Cardiotonic
Aquifoliaceae			
Ilex paraguariensis A. St.-Hil.	Yerba mate	Caffeine, theobromine, theophylline	Anti-hypertensive; cardiotonic, immunotonic, diuretic, stimulant,
Asteraceae (Compositae)			
Biden pilosa L.	Beggar's ticks	Esculetin, friedelin, limonene, lupeol	*Alterative, anti-fungal, anti-inflammatory, anti-rheumatic, styptic*
Stevia rebaudiana (Bertoni) Bertoni	Sweet herb; Ka'a He'e	Stevioside	Sweetener
Bigoniaceae			
Tabebuia impetiginosa (Mart. ex DC.) Standl.	Lapacho	Lapachol	Anti-tumor
Brassicaceae (Cruciferae)			
Lepidium meyeni Walp.	Maca	Saponins, sitosterol, stigmasterol	Anemia, aphrodisiac, menopause, tuberculosis
Rorippa indica (L.) Hiern	Nasturtium	Rorifone	Anti-tussive
Bromeliaceae			
Ananas comosus (L.) Merr.	Pineapple	Bromelain	Anti-inflammatory

Caricaceae			
Carica papaya L.	Papaya	Chymopapain, papain	Proteolytic, mucolytic
Erythroxylaceae			
Erythroxylum coca Lam.	Coca	Cocaine	Local anesthetic
Fabaceae (Leguminosae)			
Crotalaria spectabilis Roth	Rattlebox	Monocrotaline	Topical
Lonchocarpus nicou (Aubl.) DC.	Cube root	Rotenone	Piscicide
Physostigma venenosum Balf.	Ordeal bean	Physostigmine	Anti-cholinesterase
Mucuna pruriens (L.) DC. var. *utilis* (Wall.ex Wight) Baker ex Burck	Velvet bean	L-Dopa	Anti-parkinsonism
Lauraceae			
Cinnamomum camphora (L.) J. Presl	Camphor tree	Camphor	Rubefacient
Ocotea glaziovii Mez	Yellow cinnamon	Glaziovine	Anti-depressant
Lecythidaceae			
Bertholletia excella Humb. & Bonpl.	Brazil nut	Cerium, cesium, europium	Emollient, insect repellent
Loganiaceae			
Strychnos nux-vomica L.	Nux vomica	Strychnine	CNS stimulant
Malvaceae			
Gossypium spp.	Cotton	Gossypol	Male contraceptive
Menispermaceae			
Chondrodendron tomentosum Ruiz & Pav.	Curare	Tubocurarine	Skeletal muscle
Monimiaceae			
Peumus boldus Molina	Boldo	Boldin, boldine, eugenol	Diuretic, laxative, liver tonic

Olacaceae			
Dulacia inopiflora (Miers) Kuntze	Muira puama	Many including ampesterol, coumarin, lupeol, muirapuamine, phlobaphene	Aphrodisiac, rheumatism, dysentery, paralysis, menstrual cramps, menopause
Passifloraceae			
Passiflora incarnata L.	Passion flower	Harman, niacin, riboflavin, thiamin	Anti-spasmodic, anodyne, hypotonic, sedative
Piperaceae			
Piper methysticum G. Forst.	Kava-kava	Kawaina	Tranquilizer
Rubiaceae			
Carapichea ipecacuanha (Brot.) L. Andersson	Ipecac	Emetine	Amebicide
Cinchona calisaya Wedd.	Yellow cinchona	Quinidine, Quinine	Anti-arrhytmic, Anti-malarial
Uncaria tomentosa (Willd. ex Schult.) DC	Cat's claw	Many including ajmalicine, akuammigine, , catechin, cinchonain, corynantheine, corynoxeine, mitraphylline, procyanidins, speciophylline, stigmasterol, strictosidines, uncarine	Immuno-stimulant, anti-cancer, anti-AIDS
Pausinystalia johimba (K. Schum.) Pierre ex Beille	Yohimbe	Yohimbine	Adrenergic blocker;, Aphrodisiac
Rutaceae			
Pilocarpus jaborandi Holmes	Jaborandi	Pilocarpine	Parasympathomimetic
Sapindaceae			
Paullinia cupana Kunth	Guarana	Caffeine, theophylline, theobromine, guaranine, tannins, saponins	Anti-pyretic, anti-neuralgic, anti-diarrhoeal

Simaroubaceae			
Simarouba glauca DC.	Paradise tree	Glaucarubin	Amebicide
Solanaceae			
Datura metel L.	Recurved thorapple	Scopolamine	Sedative
Duboisia myoporoides R. Br.	Australian cork tree	Atropine, Hyoscyamine	Anti-cholinergic
Nicotiana tabacum L.	Tabacco	**Nicotine**	Insecticide
Physalis angulata L.	Winter cherry	Ayanin, phygrine, physagulin, physalin, withaglutin	Analgesic, depurative, diuretic, expectorant, sedative
Sterculiaceae			
Theobroma cacao L.	Cocoa, cacao	Theobromine	Diuretic; Vasodilator
Tropaeolaceae			
Tropaeolum majus L.	Common nasturtium	glucoaubrietin	Anti-septic, anti-scorbutic, decongestant, purgative
Zingiberaceae			
Curcuma longa L.	Turmeric	Curcumin	Choleretic

100 drug derivatives. Family Apocynaceae, Fabaceae, Rubiaceae and Solanaceae had four species each followed by Acanthaceae, Asteraceae, Brassicaceae and Lauraceae having two species each of medicinal plants. The remaining 23 families, including a monocotyledonous family (Arecaceae), had one species each of medicinal plants. This is by no means a comprehensive list of all of the plants, names of chemicals, or uses for those chemicals, but it should serve as a useful reference for further research. The plant parts used for medicinal purposes include bark, roots, stem, leaves, flowers, fruits and seeds. In general, medicinal plants are arranged according to their active principles in their storage organs, particularly roots, leaves, flowers, seeds and other plant parts. However,

medicinal plants are also classified according to their taxonomic position (Athar & Ahmad 2004; Athar & Nasir 2004; Athar & Siddiqi 2004; Duke 1997; Moerman 1986, 1991, 1996; Taylor 1998, 2004). Athar & Siddiqi (2004) described the taxonomy, distribution and flowering period of 95 species used as medicinal flowers in Pakistan. In another study, Athar & Ahmad (2004) studied the taxonomy of medicinal legume trees of Pakistan. In their most recent paper Athar & Nasir (2004) described the taxonomy of 78 plant species yielding vegetable oil used in cosmetics and skin and body care products.

Rainforest plants are rich in secondary metabolites, particularly alkaloids. Biochemists believe alkaloids protect plants from disease and insect attacks. Many alkaloids from higher plants have proven to be of medicinal value and benefit. Currently, 121 prescription drugs currently sold worldwide come from plant-derived sources. And while twenty-five percent of western pharmaceuticals are derived from rainforest ingredients, less than one percent of these tropical trees and plants have been tested by scientists.

The US National Cancer Institute (NCI) has several collaborative programs that screen plants for the possibility of new drugs and active plant chemicals for cancer and AIDS/HIV. Because well over fifty percent of the estimated 250,000 plant species found on earth come from tropical forests, NCI concentrates on these regions. Plants have been collected from the African countries of Cameroon, the Central African Republic, Gabon, Ghana, Madagascar, and Tanzania. Collections are now concentrated in Madagascar (one of the most rapidly disappearing rainforest regions in the world), and collaborative programs have been established in South Africa and Zimbabwe.

In central and south America, samples have been collected from Belize, Bolivia, Colombia, the Dominican Republic, Ecuador, Guatemala, Guyana, Honduras, Martinique, Paraguay, Peru, and Puerto Rico. The NCI has established collaborative programs in Brazil, Costa Rica, Mexico, and Panama. Southeast Asian collections have been performed in Bangladesh, Indonesia, Laos, Malaysia, Nepal, Pakistan, Papua New Guinea, the Philippines, Taiwan, Thailand, and Vietnam. Collaborative

programs have been established in Bangladesh, China, Korea, and Pakistan. In each country, NCI contractors work in close collaboration with local botanical institutions. The NCI has identified 3000 plants that are active against cancer cells. Seventy percent of these plants are found in the rainforest. Twenty-five percent of the active ingredients in today's cancer-fighting drugs come from organisms found only in the rainforest (Taylor 1998, 2004).

Shanley & Luz (2003) indicate the impacts of forest degradation on medicinal plant use and implications for health care in eastern Amazonia. They mention that over the last three decades, forest degradation in the Brazilian Amazon has diminished the availability of some widely used medicinal plant species. Results of their 9-year market study suggest that forests represent an important habitat for medicinal plants used in eastern Amazonia: nine of the 12 top-selling medicinal plants are native species, and eight are forest based. Five of the top-selling species have begun to be harvested for timber, decreasing the availability of their barks and oils for medicinal purposes. Many of these medicinal plants have no botanical substitute, and pharmaceuticals do not yet exist for some of the diseases for which they are used (Ebadi 2002; Gaedcke et al. 2003; Palaniswamy 2003; Ross 2003). Market surveys indicate that all socioeconomic classes in Amazonia use medicinal plants because of cultural preferences, low cost, and efficacy (Shanley & Luz 2003; Taylor 1998, 2004; Vandebroek et al. 2004). Degradation of Amazonian forests may signify not only the loss of potential pharmaceutical drugs for the developed world but also the erosion of the sole health care option for many of Brazil's rural and urban poor (Newman 1994; Shanley & Luz 2003).

Plants have provided a good source of anti-infective agents; emetine, quinine, and berberine remain highly effective instruments in the fight against microbial infections (Iwa et al. 1999; Gaedcke et al. 2003). Phytomedicines derived from plants have shown great promise in the treatment of intractable infectious diseases including opportunistic AIDS infections. Plants containing protoberberines and related alkaloids,

picralima-type indole alkaloids and garcinia biflavonones used in traditional African system of medicine, have been found to be active against a wide variety of micro-organisms (Iwu et al. 1999). Some of the rainforest medicinal plants such as cat's claw, guarana, muira puma and suma (Table 1) provide more than one useful drug derivative that are used to cure diseases including AIDS/HIV, cancer and leukemia, while others possess aphrodisiac, diuretic, cardio-tonic and immuno-stimulant properties (Duke 1997; Iwu et al. 1999; Schultes & Raffauf 1990; Werbach & Murray 1994).

The isoquinoline alkaloid emetine obtained from the underground part of *Carapichea ipecacuanha* (= *Cephaelis ipecacuanha*), and related species, has been used for many years as an amoebicidal drug as well as for the treatment of abscesses due to the spread of *Escherichia histolytica* infections. Another important plant drug with a long history of use is quinine (Iwu et al. 1999). This alkaloid occurs naturally in the bark of Cinchona tree. Apart from its continued usefulness in the treatment of malaria, it can also be used to relieve nocturnal leg cramps. Currently, the widely prescribed drug chloroquine is analogs to quinine. Some strains of malarial parasites have become resistant to the quinines; therefore anti-malarial drugs with novel modes of action are required.

Higher plants have made important contributions in the areas beyond anti-infectives, such as cancer therapies. Early examples include the anti-leukemia alkaloids, vinblastine and vincristine, which were both obtained from Madagascan periwinkle (Nelson 1982). Vinblastine and vincristine, extracted from the rainforest plant periwinkle, are one of the world's most powerful anti-cancer drugs. These drugs have dramatically increased the survival rate for acute childhood leukemia since their discovery (Gaedcke et al. 2003; Nelson 1982; Taylor 1998, 2004). Vincristine is also used to treat diabetes, fevers, and malaria, to regulate menstrual cycles, to ease excessive menstrual bleeding and as a euphoriant (feeling of well-being) (Gaedeke et al. 2003; Nelson 1982; Taylor 1998, 2004). In 1983, there were no U.S. pharmaceutical manufacturers involved in research programs to discover new drugs or cures from plants. Today, over 100 pharmaceutical companies and several

branches of the US government are engaged in plant research projects for possible drugs and cures for viruses, infections, cancer and even AIDS.

All plant species contain poisonous, medicinal and nutritional compounds (Ross 2003; Schultes & Raffauf 1990). We credit our forefathers with the intelligence to have discovered which species around them were poisonous and which were edible. Yet we sometimes seem reluctant to credit them with discovering those intermediate properties we call medicinal activities. Our forefathers discovered many, if not most of the important medicinal species tabulated herein. Farnsworth (1988) calculated that seventy-four percent of 119 plant-derived drugs were discovered as a result of chemical studies to isolate the active substances responsible for their traditional use. In other words, we are indebted to our forefathers' empirical observations for about seventy-five percent of these currently used botanicals. We may expect new discoveries and uses among these same species very soon in the coming years (Iwu et al. 1999; Palaniswamy 2003).

Evolution argues quietly for the natural drug, while economics argues loudly for the unnatural drug. Pharmaceutical firms do actively study potential medicinal plants, discovering bioactive compounds, which, with some molecular modifications, become proprietary, enabling them to recoup their investment. Here are just a few reported new uses for compounds from well-known old medicinal species: anabasine as anti-fumitory, artemisinin for malaria, chymopapain for disc problems, colchicine for cirrhosis, cynarin for choleretic activity, huperzine for anti-cholinesterase activity, hypericin for anti-retroviral activity, gammalinolenic acid for atopic eczema, lobeline as an anti-fumitory, pilocarpine for xerostomia, polygodiol for anti-yeast activity, psoralen for leukemia, sanguinarine for anti-plaque activity, silymarin for hepatitis, taxol for anti-tumor activity, tetrahydrocannabinol for glaucoma, and yohimbine for serotinergic activity.

Somewhere in the tropics, there are probably compounds that will alleviate or correct every ailment known to mankind. Let us only hope someone finds them before the species and tropical medicine chest

become extinct (Newman 1994; Schultes & Raffauf 1990). The survival of mankind is intimately dependent on the survival of forests. The more diverse tropical floras, containing more biologically active compounds, are even more threatened than the better studied temperate floras.

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